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Project West Ford

The following material is based on four reports appearing in the Astronomical Journal, *66, No. 3, pp. 105–118, April 1961. Readers interested in further details of Project West Ford, and of orbiting dipole belts in general, may wish to consult this reference. Astronomers and geophysicists, in particular, may be interested in the opportunity to observe the dipole belt.*

In the autumn of 1959, the Lincoln Laboratory of the Massachusetts Institute of Technology informed the Space Science Board of the National Academy of Sciences of a proposal to place into orbit around the earth one or more belts of thin microwave dipoles to serve as an artificial scattering medium for radio signals in the centimeter band. Each dipole is a short length of metallic wire that will reflect radio waves. Laboratory studies of this technique suggest a potential capacity to transmit perhaps hundreds of thousands of "bits" of information per second over distances as great as one-third the way around the earth.

The Board was asked to consider the effects of such a communications system on the geophysical sciences, and especially to ascertain whether the first experimental test would limit or interfere with observations in any field of basic scientific research. The papers on which this report is based describe the proposed system and reflect the opinions of a number of astronomers asked to review its probable consequences. Since Project West Ford provides an opportunity to verify theoretical calculations by direct observation, astronomers with access to suitable equipment are urged to participate in these vital studies.

Design of Proposed Experiment

Figure 1 shows how two belts of orbiting dipoles might be used with highly di-

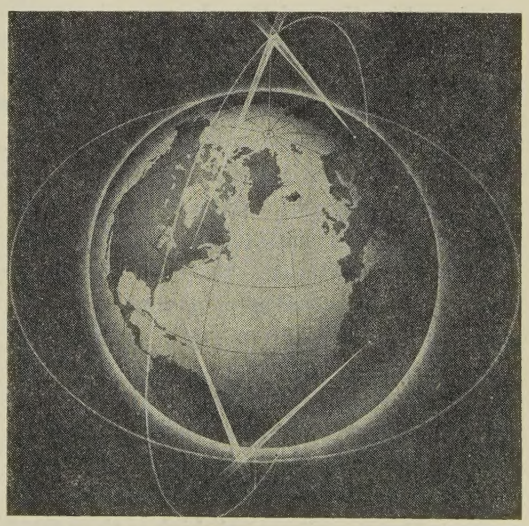

Fig. 1. *Schematic Representation of Dipole Belts in Polar and Equatorial Orbits. The manner in which such "orbital scatter" belts might relay radio messages between distant points is shown by the beams of highly directive microwave signals being reflected from the belts. (MIT drawing.)*

rectional microwave antennas to provide high-capacity communication circuits giving world-wide coverage. The following is a list of features of this technique that provide advantages over other satellite communication systems:

(1) The belts are relatively invulnerable to physical damage.
(2) No complex electronic equipment is required in space.
(3) Very large numbers of communications circuits can be provided by a single belt.
(4) Ground antennas are not required to track at high speed over large angles.

The design of the dipole system incorporates as far as possible certain desirable characteristics, including: (i) a maximum scattering cross section for radio waves per unit mass in orbit; (ii) small mass per dipole to minimize collision hazards; and (iii) an orbit high enough to make the dipole belt simultaneously visible over large areas, but at the same time having properties that would set a finite upper limit to the lifetime of the belt.

A combination of the above and certain other specifications leads to a choice of thin wire dipoles drawn from dense conducting metal (tin, copper, tungsten), with a maximum geometric area-to-mass ratio of about 50 cm^2/g. This area-to-mass ratio is low enough to minimize orbital perturbations caused by solar radiation pressure and micrometeorite collisions, but high enough to make a good reflector. The dipoles would be cut from wire 13 to 35 microns thick to a length of 1.77 cm, which is a half-wave resonant reflector for radio-frequency radiation of 8000 Mc/sec. Lower frequencies would require longer and hence more massive dipoles, thus increasing the collision hazard. Frequencies much higher than 8000 Mc/sec are subject to atmospheric and precipitation absorption effects.

For the test belt, 100 pounds of payload is available as a piggy-back arrangement on an already scheduled satellite. With this payload, approximately 75 pounds (35 kg) of dipoles could be dispersed at velocities ranging from 0.8 to 3.0 m/sec relative to the container, producing a cloud of dipoles spreading along the orbit in both directions. It is expected that it would take about 30 days for the belt to extend entirely around the earth, and that after 60 days the belt would be dispersed about 40 km in the radial direction and about 8 km perpendicular to the orbital plane. This estimate of the dispersion is based on predicted effects of the dispensing-velocity distribution and of differential orbital perturbations produced by solar radiation pressure, air drag, micrometeorites, and perhaps interaction between charged dipoles and the earth's magnetic field. Table 1 summarizes the relevant information.

Lifetime: It is important not to put objects or materials into relatively permanent orbits without prior assurance about possible harmful side effects. Therefore, the lifetime of the test belts becomes a matter of concern. At altitudes higher than 1000 km, atmospheric friction could not be depended on to bring the dipoles down, and, in general, solar radiation pressure produces variations in orbital eccentricity that are usually fairly small. However, such radiation-pressure variations can be quite large within a narrow range of altitude and orbital inclination where they become resonant with the period of precession of the major axis of the orbit. Within this narrow range

Table 1. Characteristics of West Ford Test Belt

Dipole resonance	8000 Mc
Dipole length	1.77 cm
Area-to-mass	50 cm^2/g
Belt altitude	A few thousand kilometers
Belt dimensions	8 × 40 km 60 days from launch
Mass of dipoles in belt	35 kg
Number of dipoles in belt	3.5×10^8
Average separation of dipoles	370 m
Density of dipoles	21 per km^3 60 days from launch

the periodic lowering of perigee might well limit the lifetime to one or two years; outside this range the belt lifetime might be one or two decades.

Another possible way of limiting the lifetime, currently under investigation, is to make the dipoles of white tin alloy, which disintegrates into gray tin powder under conditions in space. Solar radiation pressure may then bring the powder to earth.

Reflective Properties of the Orbiting Dipoles: A dipole reflects radiation most efficiently under the following circumstances: (i) when the wavelength (λ) of the incident radiation is twice the length of the dipole; (ii) when the wave front is parallel to the long dimension of the dipole; (iii) when the reflected wave front is also parallel to the dipole; and (iv) when the reflected ray is turned back 180° on the incident ray (i.e., back scattered).

Under the optimum circumstances listed above, the scattering cross section would be 0.89 λ^2, but the random orientation of the tumbling dipoles and departures from optimum polarization of the antennas would reduce it to about a tenth this value. The dipoles would also be quite resonant for integral multiples of the fundamental frequency. For still higher frequencies (in the far infrared), the length of the dipole is no longer critical. Finally, in near infrared and visible frequencies, where the wavelength of the radiation becomes shorter than the diameter of the wire, the reflection cross section levels off at its geometric value.

For longer wavelengths, i.e., for frequencies lower than the resonant frequency, the scattering cross section decreases as the fourth power of the frequency (Rayleigh scattering). The above discussion is summarized in Figure 2.

With these reflective properties in mind, it is possible to estimate the effects of orbiting dipole belts on astronomical measurements in the optical and photographic wavelength regions and on radio astronomy

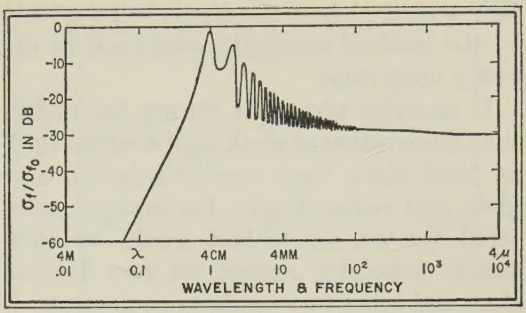

Fig. 2. *Scattering Cross Section (σ_f) of a Dipole as a Function of Wavelength or Frequency. The resonant frequency, f_o, which equals 1 on the normalized scale of the diagram, is 8000 Mc/sec. Cross-section scale gives the power re-radiated by a dipole, at frequency f, in terms of decibels (db) below the power at resonant frequency. (Curve for first four resonances adapted from MIT drawing, as published in* Astronomical Journal, *April 1961; high-frequency resonances are schematic.)*

observations, and to determine the likelihood of interference with existing communication, navigation, or radar systems. The mass, shape, and distribution of the dipoles also determine the extent of the collision hazard.

Effects at Optical Wavelengths

Two principal properties of orbiting dipoles that might affect visual, photographic, or photoelectric observations in optical wavelengths have been considered: (i) the attenuation of light transmitted through the belt, and (ii) scattering of light by the dipoles, principally sunlight.

The maximum possible attenuation of transmitted light would be proportional to the product of the belt thickness, the density of dipoles per unit volume, and the average projected geometric cross section (see Table 1 for numerical data). Thus, maximum attenuation is: 40 km $\times$ 3 $\times$ 10^{-2} cm^2/km^3 = 1.20 cm^2/km^2, or about 1 part in 10^{10}, a degree of attenuation not measurable by present techniques. It is also clear that light diffracted from the transmitted ray by the dipoles would not produce a detectable amount of scintillation, and that the star-

light scattered from the dipole belt ($<10^{-10}$ $\times$ the incident starlight) would not be directly observable.

It appears, also, that during the nighttime observation of weak light sources, such as faint stars, very remote galaxies, airglow, and zodiacal light, the sunlight scattered by the dipole belt would be only barely detectable against the very darkest skies and using very sensitive equipment.

This scattered sunlight may be more readily detectable, however, from the orbiting observatories expected to be launched during the next several years to altitudes above the atmospheric airglow. The estimated flux at the earth's surface of sunlight illuminating the proposed test belt is equivalent to about 1.6 tenth-magnitude stars per square degree, assuming that a tenth-magnitude star is about 2×10^{-15} times as bright as the sun. Magnitudes of some natural sources of night-sky brightness, in terms of tenth-magnitude stars per square degree, may be considered for comparison. Zodiacal light ranges from 40 at the ecliptic poles to 300 in the ecliptic plane toward the direction of the sun. The light from unresolved stars varies from perhaps 10 near the poles of the Milky Way to 200 in the galactic equator. The airglow, darkest in the zenith and brightest near the horizon, contributes a roughly equal amount, but this is chiefly radiation that can be filtered out.

Even after diffusing for 60 days, the dipole belt would be only a few tenths of a degree wide as seen from the surface of the earth. The apparent angular motion of the belt resulting from the earth's rotation would carry it across the line of sight in less than half a minute at the zenith and in less than three minutes near the horizon. These short times, together with the very weak surface brightness of the belt, would obviously make the belt very difficult to observe with ordinary techniques.

In order to verify these conclusions, astronomers and other interested persons are being urged to make whatever photographic, visual, or photoelectric observations they can. There are several important possibilities. The growth of the cloud of dipoles with time may be followed by use of fast, wide-angle cameras and combinations of filters and emulsions that reject bright airglow radiations at wavelengths such as 3914, 5577, 6300, 6363 Angstroms, and others. For absolute-intensity information, photographs and photometric measurements should be calibrated against known standards, either laboratory light sources or astronomical objects such as the Andromeda galaxy, the Magellanic Clouds, and other previously well-measured bright surfaces.

Sensitive photoelectric photometers capable of detecting signal-to-noise ratios of the order of 10^{-2} would yield very valuable data on the growth and scattering properties of a dipole belt, especially if measurements were made in several colors or spectral regions. Polarimeter measurements with photoelectric equipment, or possibly even with the naked eye, would be especially useful in determining whether the dipoles in the belt have any tendency to assume a preferential alignment, through possible interaction with the earth's electromagnetic field or as a result of atmospheric drag.

In studies thus far, very little consideration has been devoted to what effects would arise if the solid-metal dipoles were to sublimate entirely. Some astronomers suspect that scattering effects and the bright line spectrum from metallic vapor might be more readily observable than the scattering of the continuous solar spectrum discussed in the foregoing paragraphs.

Effects on Radio Astronomy

Radio astronomy observations are carried out in wavelengths ranging from several meters down to less than one centimeter. Radio measurements may be affected by the orbiting dipole belts in three different ways: (i) by attenuation of radiation passing through the belt; (ii) by causing angle-of-arrival fluctuations, analogous to optical scintillation; (iii) by reflecting or scatter-

ing extraterrestrial radiation and terrestrial radio signals.

The attenuation effects would be greatest at the resonant frequency, corresponding to a wavelength of 4.0 cm. Sixty days after launch, it is estimated, the total scattering cross section of the dipole belts (i.e., the cross section per dipole of random orientation times the number of dipoles per cubic km along the line of sight) would be 32 cm^2/km^3. Thus, about one ten-millionth of the 4-cm radiation would be removed from a ray passing through the thickest part of the belt. The effects at other frequencies would be smaller, in proportion to the smaller scattering cross sections (see Fig. 2). The attenuation by the dipole belt is, in any case, negligible in comparison to the total attenuation along a vertical path through the troposphere, which is more than 10,000 times greater at 8000 Mc/sec than the belt attenuation.

It is estimated that the fluctuation in angle of arrival of radio waves passing through the dipole belt would be in the vicinity of one-millionth the angular width of the belt as seen from the ground. Again, this scintillation is negligible in comparison with that produced by natural phenomena.

As with attentuation and scintillation effects, which would probably not be detectable, it is estimated that radio-frequency radiation of natural origin (i.e., from the sun, moon, planets, radio stars, etc.) that is scattered by the orbiting dipoles would be several orders of magnitude below the sensitivity threshold of the best radio telescopes now in use. In reaching this conclusion, temperature of the earth and moon was assumed to be 300° Kelvin; the sun's temperature was assumed to be 10,000°K at a wavelength of 4 cm during quiet periods, and up to 1,000,000°K during periods of solar activity. The dipole belt, dispersed as it would be after 60 days, and as viewed from a distance of 4000 km, would raise the background temperature by about 4.7×10^{-6}°K on the average; somewhat higher peaks would occur during times of solar activity, but they would still be much too weak to detect.

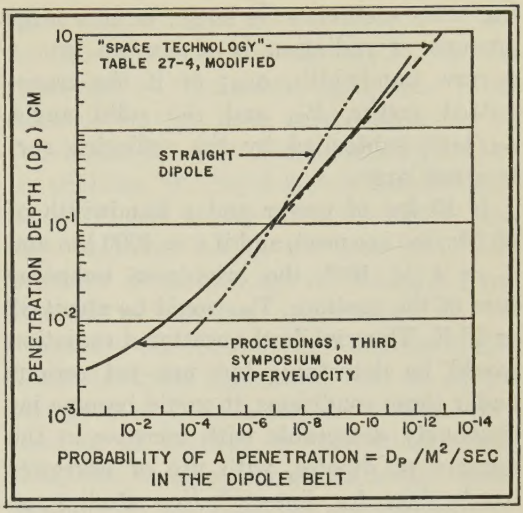

Fig. 3. *Probability of Penetration of a One-Square-Meter Surface Area to Various Depths, Dp, per Second of Exposure in the Dipole Belt. Also shown are similar curves for micrometeoroid penetration, based on data from the sources indicated. (Adapted from MIT drawing published in* Astronomical Journal, *April 1961.)*

The situation is altogether different, however, for the much stronger radio signals emitted by transmitters on the ground. The apparent "brightness temperature" of the scattering medium (T_M), which is a measure of the scattered power per unit bandwidth, is given by the relation $T_M = (\sigma/k\Delta\nu_R)(P_T\Delta_T/4\pi r^2)$, in which σ is the total scattering cross section; k is "Boltzmann's constant" (1.38×10^{-16} ergs/degree/particle), which can be regarded as a conversion factor to convert the average energy of moving charged particles to the temperature of the medium made up of the particles collectively; $\Delta\nu_R$ is the receiver bandwidth (assumed to be not wider than the transmitter bandwidth); P_T is the transmitter power; Δ_T is the effective area of the transmitter antenna; and $4\pi r^2$ is the area of a sphere whose radius, r, is the distance of the transmitter from the scattering medium.

According to this formula, the scattering medium will appear brighter if the scatter-

ing cross section, σ, is large; or if a large amount of radiation is channeled into a narrow bandwidth, $\Delta\nu_R$; or if the transmitted power, P_T, and the solid angle, $\Delta_T/4\pi r^2$, subtended by the radiation surface are large.

If 10 kw of power and a bandwidth of 10 Mc/sec are used, and if r = 4000 km and $\sigma = 4 \times 10^{-8}$, the brightness temperature of the medium, T_M, would be about 3° or 4° K. Thus, while the scattered radiation would be detectable but not yet serious under these conditions, it would become increasingly detectable with increase in the number of dipoles, with use of narrower bandwidths for line-radiation studies, or with use of larger numbers of higher-powered transmitters. It is necessary, therefore, that radio astronomers keep themselves informed concerning these factors.

Collision Hazards

The likelihood of damage arising from the collision of a space vehicle with a dipole has been estimated. Such an impact would cause the dipole to pentrate most deeply when the dipole and its velocity vector were aligned so that the dipole would pierce a flat surface perpendicularly. The depth of penetration (D_p) is given by the formula $D_p = L(\rho_d/\rho_s)^{1/2}$, where L is the dipole length, ρ_d the dipole density, and ρ_s the density of the space vehicle's surface material. The probability that a dipole would actually be aligned so as to achieve this maximum penetration, however, is extremely small (approximately one in one million).

The likelihood of a single penetration by a dipole to a specified depth within a one-square-meter area of the surface of a space vehicle is shown graphically in Figure 3. The curve is based on probabilities for various velocity vectors of the randomly oriented dipoles and on dispersion of the dipoles in the volume of space occupied by the test belt. Probabilities of penetration resulting from micrometeoroid collisions, based on initial data from the Explorer I satellite, are also shown.

Finally, bearing in mind that a satellite or rocket would spend only a very small fraction of its lifetime inside the dipole belt, it can be seen that the likelihood of a damaging collision with a dipole is quite minute.

Note:

Since the foregoing material was submitted for publication, the Space Science Board has prepared a summary report of its activities and findings regarding Project West Ford. This report, which includes the full text of a policy position announced by the United States Government on August 11, will appear in the September 1961 issue of the Bulletin. *In substance, the policy position states that no further launches of orbiting dipoles will be planned until the results of the West Ford experiments have been analyzed and evaluated, that decisions to place additional quantities of dipoles in orbit will be contingent upon this evaluation and the development of the necessary safeguards to protect space activities and any branch of science, and that astronomers throughout the world should be invited to cooperate in making measurements of the West Ford experiment.*

Mass Accumulation in West Antarctica

The following material was prepared by Mario B. Giovinetto, Institute of Polar Studies, Ohio State University.

The rate of mass accumulation is an important element in an understanding of the energy and mass budgets of the Antarctic ice sheet. For a particular location, the rate of snow-and-ice accumulation can be obtained through interpretation of the snow stratigraphy—the characteristic patterns developed in snow layers as a result of seasonal variations of the weather. These stratigraphic patterns can be traced horizontally in the upper layers of snow, and annual accumulation layers can be identi-

fied. (*Bulletin No. 23* contains an earlier report on Antarctic snow stratigraphy.)

Computations of the thickness and density of each annual accumulation layer at a location sampled permit an estimate of the net rate of accumulation in terms of the water equivalent of the snow and ice in the layers. Such values cannot generally be regarded as absolute, however, except for points where stratigraphic analysis is substantiated by direct measurements of accumulation (usually with stakes) or by geochemical analyses. Between substantiated points along a series of stratigraphic sample sites, values derived solely by interpretation of snow stratigraphy are assumed to represent the general trend of accumulation.

After accumulation values are obtained, a further step toward an understanding of the mass budget is to correlate these values with atmospheric circulation. Such a correlation may be relatively easy on the continental scale, but on the regional scale problems frequently emerge that require more-detailed study. At present, several investigations are under way concerning the relationship of snow accumulation to circulation patterns of both continental and regional extent.

Areas of Coverage and Sources of Data

This report is concerned primarily with accumulation in West Antarctica. During the last five austral summers, fifteen major US glaciological-seismological traverse parties, both oversnow and airborne, have gone into the field from Little America, Byrd, and Ellsworth IGY Stations, and from the Naval Air Facility at McMurdo Sound. (*Bulletin No. 39* contains a map showing the routes of most US traverses through the 1959–60 summer.)

Portions of the data collected in the field by V. Anderson on the Byrd Station Traverses of 1956-57 and 1957-58, by H. Neuberg on the Ellsworth Station Traverse of 1957-58 and the Marie Byrd Land Airborne Traverse of 1958-59, by W. Long on the Byrd Station Traverse of 1958-59, and by M. Giovinetto at Byrd and South Pole Stations and at Camp Michigan, near Little America Station, have been interpreted by Giovinetto for this report. (See Figure 4.) In addition, W. Boyd and A. Stuart have analyzed, and kindly made available, data they collected during the Ross Ice Shelf Traverse of 1957-58 and the Victoria Land Traverse of 1959-60, respectively.

Because the route of the Commonwealth Trans-Antarctic Expedition, 1957-58, passed over parts of West Antarctica or came very close to its borders, accumulation values along this route, obtained and kindly made available by H. Lister, are also included.

Accumulation Values

The values of net annual accumulation shown in Figure 4 are based on analyses of approximately one-half the glaciological data available; with only a few exceptions, they are preliminary in nature. Average annual accumulation values for the individual stations were computed from analysis of three to eight consecutive annual layers, for periods beginning in 1950 or earlier.

Direct measurements were obtained with accumulation stakes at a few of the stations along routes over which the several series of stratigraphic studies were made. The stake measurements were obtained over periods of one to three years, and the annual accumulation values thus computed agree with related values determined from stratigraphic interpretations. For stations between these known points, accumulation trends are inferred.

The accumulation values shown in Figure 4 present a recognizable pattern. It can readily be seen that the region of largest annual accumulation in West Antarctica is the Bellingshausen Sea—Sentinel Mountains region. In the vicinity of the Sentinels, water-equivalent values of 24-29 cm/year were obtained, and current studies by M. J. Rubin and Giovinetto, of the relation between accumulation and atmospheric circulation, indicate that accumulation in the

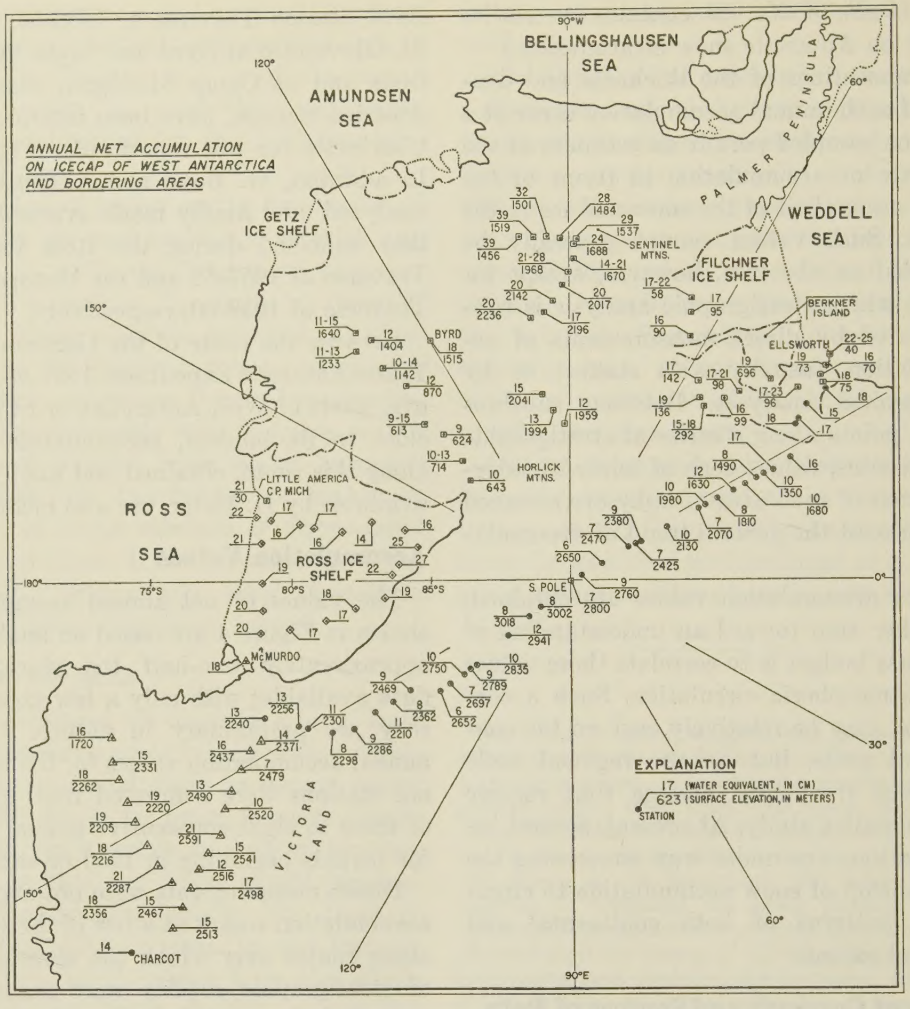

Fig. 4. *Mass Accumulation on West Antarctic Icecap and Bordering Icecap Areas. Accumulation (upper figure for each station) is given in centimeters of water equivalent and represents the annual net value for the station. Elevation, in meters, is also shown for most stations (lower figure). Sites sampled by US teams during the 1956–57, 1957–58, 1958–59, and 1959–60 austral summers are indicated by squares, triangles, and diamonds, and their data were analyzed by M. B. Giovinetto, A. Stuart, and W. Boyd, respectively; sites sampled during the Commonwealth Trans-Antarctic Expedition, 1957–58, are circled, and their data were analyzed by H. Lister. Map prepared by Giovinetto.*

coastal belt just south of the Bellingshausen Sea may be as great as 60 cm/year, or greater. This may also be the region of greatest annual accumulation in all of Antarctica. (An earlier report, by R. L. Cameron and R. P. Goldthwait, 1960, suggests that greatest accumulation may occur in the coastal region between 5° E and 10° W, in East Antarctica.)

As indicated by the map, annual accumulation generally decreases toward the high interior plateau region, with the lowest values occurring along the route of the Commonwealth Trans-Antarctic Expedition. Values in the vicinity of the geographic South Pole are especially low, ranging from 6 cm/year, the minimum obtained from these data, to about 9 cm/year of water equivalent. Values comparable to this were also obtained in Victoria Land by Lister

and Stuart on the basis of stratigraphic interpretations, but stake measurements by A. P. Crary in south Victoria Land and snow-stratigraphy studies along the route of the McMurdo-South Pole traverse, 1960-61, yielded still lower accumulation rates than those of Lister and Stuart.

A pronounced east-to-west decrease in accumulation in central West Antarctica can also be seen, falling from the high near the Sentinel Mountains and Bellingshausen Sea coast to lows of 9-15 cm/year near the eastern margin of the Ross Ice Shelf. Accumulation values on the ice shelf itself are about intermediate between the highest and lowest in West Antarctica, and values for both the Ross and Filchner ice shelves are approximately similar.

From the values presented here, the average accumulation in West Antarctica (excluding the Palmer Peninsula) is estimated to be 18 $\pm$ 2 cm/year.

Problems in Snow-Stratigraphy Interpretation in the Antarctic

Analyses of the original stratigraphic data have revealed certain factors that make some areas more difficult to interpret than others. In general, the difficulties of stratigraphic interpretation increase from the Weddell and Bellingshausen Sea coasts toward the Byrd and South Pole stations. The Ross Ice Shelf is relatively easier to interpret than the polar plateau of West Antarctica, and the most difficult area for stratigraphic interpretation is Victoria Land, in East Antarctica.

Interpretation in interior areas, and particularly in Victoria Land, is made difficult by two factors: (i) excessive sublimation resulting from large temperature differences between the upper snow layers and the air, causing a vertical mass transport within the snow that may obliterate some horizons entirely (see *Bulletin No. 23* for a more-detailed explanation of this process); and (ii) irregular distribution of the snow accumulating on the surface, resulting mostly from wind action. The latter effect is also strong in the vicinity of the South Pole.

At several localities in Victoria Land, layers of large, soft grains and crystals formed by sublimation effects were more than 50 cm thick. The frequency of occurrence of this phenomenon appears to increase from the margins of the Ross Ice Shelf toward the interior of East Antarctica, and an extreme development of it was seen at the easternmost station occupied by the 1958-59 Victoria Land Traverse party. At this station, at 78° 03′ S, 131° 43′ E, sublimation crystals made up 133 of the upper 166 cm of the snow strata.

Summary and Conclusions

Analyses of snow-stratigraphy and comparisons, at some points, with accumulation-stake data show patterns of mass accumulation for West Antarctica and bordering portions of East Antarctica. It is seen that accumulation generally decreases toward the higher interior areas, and it appears that the region of maximum accumulation is in the vicinity of the Bellingshausen Sea. Average accumulation in West Antarctica, excluding the Palmer Peninsula, is estimated to be about 18 cm/year.

Where corresponding measurements were available, accumulation values interpreted from snow stratigraphy were in general agreement with those obtained by measurements using stake networks. This general agreement between results of the two methods was found at virtually all permanent scientific stations, including the Ellsworth, Byrd, South Pole, and Little America (Camp Michigan) IGY stations and at NAF McMurdo. However, at Charcot Station (Fr.), stratigraphic interpretation yielded a value nearly twice that measured with stakes.

While accumulation values between the permanent stations are not yet substantiated, they are believed to represent the existing trends of geographic distribution of mass accumulation on the ice sheet of West Antarctica.

Explorer XI Gamma-Ray Satellite

Explorer XI (1961 Nu), carrying instrumentation to detect and measure in nearby space gamma radiation produced by galactic cosmic rays, was launched from Cape Canaveral, Florida, by the US National Aeronautics and Space Administration at 9:16 am EST (14:16.38 UT), April 27, 1961. Nine minutes later (14:25.35 UT) the satelite was injected into orbit at approximately 27°N, 66°W.

Orbital data a few weeks after launch were as follows: perigee, 490.8 km (305 statute miles); apogee, 1780.9 km (1106.6 statute miles); orbital inclination 28.8°; and period, 108.03 minutes. The experiment is expected to have a lifetime of about one year, and the satellite will probably remain in orbit for several years.

The satellite was boosted into orbit by a four-stage Juno II rocket, furnished by NASA's Marshall Space Flight Center, Huntsville, Alabama. The Juno II consists of a modified Jupiter first stage, developed orginally by Marshall personnel, and three solid-propellant upper stages provided by the NASA Jet Propulsion Laboratory, Pasadena, California.

Immediately after it was certain that orbit had been achieved, the Space Science Board of the US National Academy of Sciences sent a telegram to the Committee on Space Research (COSPAR), in The Hague, providing orbital information and experimental details for transmission to all COSPAR participants. Data obtained during the course of the experiment will also be forwarded to COSPAR for dissemination to participants and will be deposited in the IGY World Data Centers.

Experimental Objectives

The primary objectives of the Explorer XI experiment are (i) to detect extra-terrestrial high-energy gamma rays, (ii) to map their distribution in terms of direction of arrival, and (iii) to relate these measurements to the cosmic-ray flux density and to the density of intersteller matter throughout our galaxy. Gamma rays in space are produced by the decay of electrically neutral pi-mesons, which are, in turn, produced by collisions between primary cosmic rays and atomic nuclei (possibly of interstellar hydrogen or dust). Thus, the Explorer XI experiment may provide new knowledge about the origin of primary cosmic rays.

Because they are electrically charged, the high-velocity protons making up the bulk of inflowing galactic cosmic rays are deflected by the earth's magnetic field, as well as by magnetic fields in space. Hence, it is difficult to determine their true direction of origin. The highly energetic gamma rays, however, are electromagnetic in nature—as are visible light, X-rays, and ultraviolet radiation—and bear no electrical charge. Since they are unaffected by magnetic fields, the gamma rays can provide an indirect measure of both intensity and direction of arrival of the primary cosmic rays from which they are derived.

Gamma rays are also produced in the earth's atmosphere by cosmic-ray protons that have already been deflected from their original paths by the geomagnetic field, and by protons from the Van Allen radiation belts. Moreover, gamma rays originating beyond the earth's atmosphere cannot generally be distinguished from those generated within the atmosphere. Therefore, in order to use this technique for study of galactic cosmic rays, an instrument platform of known orientation capable of measuring gamma radiation through a large area of space above the masking effects of the atmosphere was required. Explorer XI provides such a platform.

Description of Satellite

The Explorer XI payload is 88.8 inches long over-all, weighs a total of 95 pounds, and, along with the attached fourth-stage

rocket, resembles an old-fashioned street lamp. (See Figure 5.) The 44.5-inch-long, 12.8-lb, burned-out fourth-stage rocket is included in the payload configuration to provide additional length and weight needed to maintain a tumbling motion of the satellite (see below); it also acts as part of the transmitting antenna. The gamma-ray "telescope" is contained within an octagonal aluminum box, 11 inches in diameter and 21 inches long, mounted on a 6 × 20.5-inch aluminum instrument column. In addition to housing the gamma-ray detector, the box provides four external surfaces for the satellite's solar cells.

As it travels along its orbit, Explorer XI tumbles end-over-end to enable the telescope, which is aimed outward from the end of the octagonal box, to scan as large a portion of surrounding space as possible. (See Figure 6.) The rate of tumbling varies somewhat, but initially it was about 5 revolutions per minute. A four-lb weight placed near the nozzle of the fourth-stage rocket also helps to achieve the ratio of moments of inertia along the transverse and longitudinal axes necessary to maintain the tumbling motion.

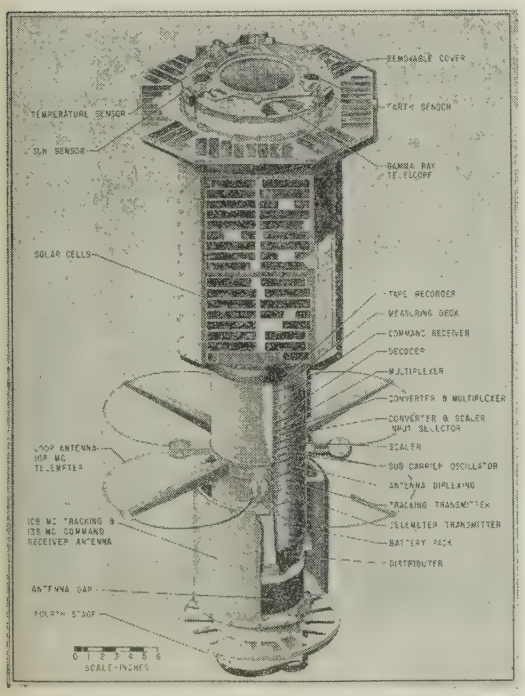

Fig. 5. *Explorer XI Gamma-Ray-Astronomy Satellite (cutaway view) Showing Configuration and Instrumentation. NASA drawing.*

Instrumentation and Experimental Technique

The Explorer XI gamma-ray experiment is conducted under the direction of William Kraushaar and George Clark of the Massachusetts Institute of Technology, and the satellite's gamma-ray telescope was developed and built at MIT. The supporting electronic equipment for the experimental instrumentation, as well as the payload structure itself, were designed and built at NASA's Marshall Space Flight Center.

The gamma-ray telescope used in Explorer XI consists essentially of a combination of radiation detectors—a "sandwich" scintillation detector, a Cerenkov detector, and a plastic scintillator that serves as an anti-coincidence shield—together with circuitry capable of distinguishing between the different forms of radiation striking the detectors and screening out all but gamma radiation. The system is quite versatile, however, and, on command from the ground, the other types of radiation can also be observed. The telescope is designed to detect gamma rays with energies greater than about 70 million electron volts entering through an acceptance cone having a half-angle of about 15°. The instrument's axis of sensitivity rotates in the plane of the satellite's tumbling motion (see Fig. 6).

The sandwich detector consists of two layers of sodium iodide (NaI) sandwiched between three layers of cesium iodide (CsI). Each layer is 7.6 cm in diameter and 0.5 cm thick, and the whole assembly is optically coupled to a single phototube to detect light flashes in the sandwich stack. The electronic system produces two signals for every scintillation event in the sandwich detector—one, a fast signal, is proportional to the pulse amplitude from the NaI layers

and the other is proportional to the total-pulse amplitude from all five layers.

The Cerenkov detector, situated behind the sandwich detector, has a cylindrical lucite radiator, 7.6 cm in both diameter and length, which is viewed from the back by two phototubes; this detector responds selectively to very-high-energy charged particles traveling from the direction of the sandwich detector. The shield, covering the solid angle in front and on the sides of the sandwich and Cerenkov detectors, is a plastic scintillator viewed by five phototubes.

An incoming gamma ray first passes through the shield, without causing a scintillation pulse since it is uncharged. Upon striking a nucleus in the sandwich of crystalline NaI and CsI layers, the gamma ray produces a positron and an electron. These, in turn, pass through the remaining layers, causing scintillation pulses, and continue out the back of the telescope through the Cerenkov detector, once again causing scintillation. Thus, to record the passage of a neutral particle, approximately coincident signals must be generated by both the sandwich and Cerenkov detectors, *unaccompanied* by a coincident pulse from the shield.

As neutrons generated locally by interactions of charged cosmic rays in the satellite structure can cause the same sequence of events as gamma rays, the telescope must also distinguish between these two types of neutral particles. This is done by differences in excitation, when struck by either gamma rays or neutrons, of the two types of materials used in the sandwich detector—NaI and CsI. These differences in excitation are indicated by differences in the fast and total pulses from the sandwich detector. Gamma rays cause approximately equal excitation in the two materials, while neu-

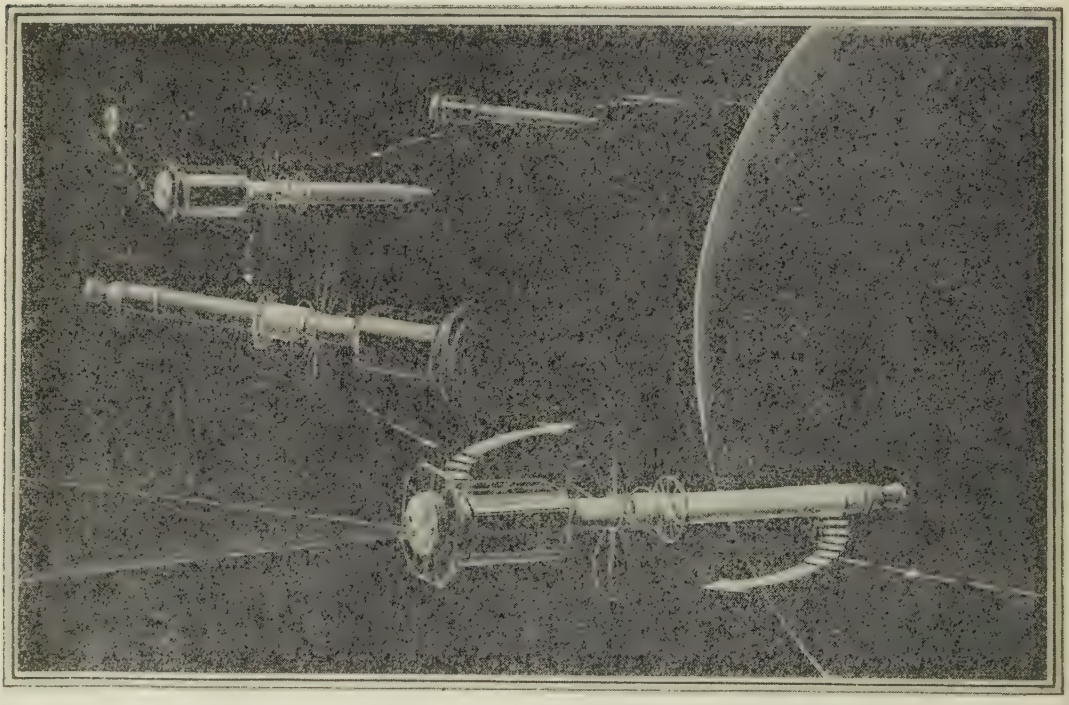

Fig. 6. *Explorer XI and Attached Fourth-Stage Rocket Casing. End-over-end tumbling motion is designed for maximum coverage by gamma-ray telescope. Disk leaving top of payload is micrometeorite shield to protect telescope; shield can be removed by ground command near end of experiment lifetime (about one year) to provide data for distinguishing between gamma radiation produced when cosmic rays strike the shield and that actually coming from space. The two beams projecting from end of satellite (foreground) show "lines of sight" of sun and earth sensors. NASA photograph.*

trons generally cause local concentrations of energy in the layer in which the interaction occurs.

Two optical-aspect sensors aimed forward along the telescope axis produce characteristic signals when they scan across the earth's horizon or twilight zone, or close to the sun. Knowledge of the satellite's aspect at all times, coupled with the directional character of the telescope, permits the direction of arrival of the incoming gamma rays to be determined.

Preliminary Results: Preliminary analyses of real-time data telemetered by Explorer XI during its first few weeks in orbit indicate that radiation background intensity approximately followed prior estimates by the experimenters. Gamma-ray counting rates were also generally as expected. Several months of data acquisition are needed, however, before firmly based conclusions on gamma-ray distributions in space can be reached.

Initial data on satellite temperatures showed a range of about 30° C to 50° C (about 85°-120° F) for the battery pack, temperatures usually very close to 30° C for the experimental package, and about 4°-23° C (39°-73° F) for the solar cells.

Radio and Telemetry Equipment

The satellite is powered by a system employing solar cells to charge nickel-cadmium batteries, and carries two phase-modulated transmitters. Frequency-modulated outputs from the various sub-systems are combined in two mixing amplifiers. The output of one of these amplifiers goes to a low-power, phase-modulated transmitter operating continuously on a frequency of 108.06 megacycles, with a power output of 20 milliwatts, and radiated by a split dipole antenna made up of the two halves of the satellite structure (payload and fourth-stage rocket).

The output of the second mixing amplifier feeds a tape recorder, which in turn feeds a higher-power (125 milliwatt), phase-modulated transmitter. This transmitter is connected to a loop antenna whose plane is perpendicular to the longitudinal axis of the satellite structure. The recorder records continuously for 100 minutes and plays back the stored data in two minutes.

In the first few weeks after the date of launch, real-time data was telemetered satisfactorily, resulting in acquisition of about 50% of the total usable data obtained by the satellite. The satellite tape recorder, however, has not functioned properly.

Tracking and Data Acquisition

The NASA Minitrack system is being utilized for tracking and data reception. Approximately ten stations track the Explorer XI satellite and receive data transmitted over the low-power transmitter. Four of these stations were also to receive and record tape-recorded data from the satellite's high-powered transmitter. However, because of the malfunction of the tape-recorder, it has been necessary to expand acquisition of real-time data by addition of telemetry acquisition stations, in Hawaii, in California, and possibly in India. Analysis and interpretation of the data received from the satellite is being carried out at the Massachusetts Institute of Technology.

SPACEWARN

Communications Network for World-Wide Rapid Dissemination of Satellite Information

The following report is based on material prepared by A. H. Shapley, Vice-Chairman of the US National Committee for the IGY and Spokesman for ICSU International World Days Service.

Mindful of the need for the rapid dissemination of information on IGY satellite launchings and orbits, the CSAGI Rocket and Satellite Conference, held in Washington, D. C., October 1957, and the Fifth Meeting of CSAGI, held in Moscow in August 1958, recommended that the IGY World Days communication network (see *Bulletin Nos. 5, 23,* and *47*) be made available for this purpose. Accordingly, during IGY and IGC-59, this communication channel was used for satellite launching announcements, orbital predictions, and approximate tracking observations, as well as for its original purpose of alerting geophysicists throughout the world of impending solar-terrestrial events, or of their onset.

At the third meeting of the Committee on Space Research (COSPAR—established by the International Council of Scientific Unions in 1958), held in Nice, France, January 1960, it was concluded that an international channel for rapid communication of prediction information needed for tracking and conducting other satellite observations should continue to be available. COSPAR accordingly recommended that the IGY World Warning Network continue to be used for this purpose, under the name of SPACEWARN.

The main types of messages transmitted by SPACEWARN are launching announcements, orbital predictions, and approximate tracking observations. The messages go from one continent to another by telegram, and further distribution to national centers and individual laboratories is accomplished by the most effective rapid means available.

SPACEWARN Network

The SPACEWARN network for rapid communication of satellite information consists of four Satellite Regional Warning Centers (SRWC), located as follows (telegraphic addresses are given in parentheses):

Western Pacific
Radio Research Laboratories
Kokubunji, Tokyo, Japan
(AGI KOKUBUNJI)

Western Europe
Fernmeldetechnisches Zentralamt
Rheinstrasse 110
Darmstadt, German Federal Republic
(IONOSPHARE DARMSTADT)

and Radio Research Station
Ditton Park
Sloughs (Bucks.), England
(RADSEARCH SLOUGH)

Eurasia
Astronomicheskiy Sovet
Akademii Nauk
Bol'shaya Gruzinskaya
dom 10, Moscow, USSR
(COSMOS MOSCOW)

Western Hemisphere
North Atlantic Radio Warning Service
Box 178
Fort Belvoir, Virginia, USA
(AGIWARN WASHINGTON)

Associate centers, which handle some satellite message traffic, are located in the Netherlands and at Sydney and Salisbury, Australia.

In general, satellite information is delivered to the network at AGIWARN or COSMOS. A message is then sent by telegram to each of the other three SRWC's for distribution to stations within the SRWC regions according to the regional plans. In the Western Hemisphere, for example, announcement of the successful launching of a United States scientific satellite is telegraphed to AGIWARN by the Space Science Board of the US National Academy of Sciences. The message is then transmitted

by AGIWARN over the SPACEWARN network, usually within one hour of receipt, directly to the other SRWC's, to the associate centers in the Netherlands and Australia, and to Western Hemisphere and US addresses that have standing requests for such information.

Launching Messages

The SRWC for the Western Hemisphere (AGIWARN) has received from United States launching authorities, and distributed internationally, 19 launch messages, for the following US scientific satellites and space probes: Explorer I, III, IV, VI, VII, VIII, IX, X, XI, and XII; Vanguard I, II, and III; Pioneer IV and V; Tiros I, II, and III; and Echo I. The message is identified by the code word LUNAVER, followed by digits indicating the date and time of the message. The body of the message is simply worded, providing, as appropriate, the following information: scientific and popular names of satellite or probe; launch and injection dates and times; coordinates of injection point; launch site; preliminary orbital elements; shape, size, and weight of payload; summary description of scientific instruments; radio frequencies and power for tracking and telemetry; and related information. The signature is AGIWARN.

On three occasions (for Sputnik III and Lunik II and III), announcements of USSR launchings were distributed over the World Days network. In August 1961, a launching message from the USSR, concerning the Vostok II manned spacecraft, was received by the IWDS Spokesman and introduced into the SPACEWARN network.

Orbital Predictions

Predictions of the future paths of satellites are expressed as (i) "station predictions," applicable to a specified tracking station and a specified passage of the satellite; (ii) "sub-satellite points," giving the coordinates and time of passage over one or more points of a terrestrial grid (for example, longitude and time of passage over the equator); or (iii) orbital elements, or the so-called "modified orbital elements," from which the time and aspect for any tracking location can be computed for any passage. It is to be noted that (ii) and (iii) are of widespread or universal applicability, while (i) is of use only to the particular tracking station concerned.

AGIWARN receives from US computing centers the current modified orbital elements for most satellites and distributes them internationally over the SPACEWARN network in an abbreviated coded message form. These AGIWARN messages are identified by the code word LUNACEN, followed by a date-time group. The body of the message, introduced by the code word SATOR (see below) and specifying the satellite and epoch, is in the SATOR code. In 1960, AGIWARN distributed 248 SATOR messages concerning 17 satellite objects. Such messages have not yet been introduced into the SPACEWARN network from COSMOS.

Equatorial-crossing predictions are provided to AGIWARN for certain satellites and are distributed by mail. Station predictions, in accordance with conclusions reached at the Nice meeting of COSPAR, should in general go directly from computing centers to the respective stations, utilizing the SPACEWARN network only under special arrangements. During 1960, no station-prediction messages flowed through SPACEWARN; the last one was sent in March 1959 from COSMOS to a station in Ecuador.

Tracking Observations

The SPACEWARN network has provided a channel for the prompt reporting of tracking observations to computing centers for the purpose of improving future predictions. Tracking data are not interchanged among all SRWC's; in general, they are sent by the tracking station headquarters to the nearest SRWC, which then forwards them to the SRWC in the region of the com-

puting center of the launching agency. In this case, the SPACEWARN network serves as an international channel for communication from a particular tracking station to a particular computing center, although in principle the data are available to any interested group.

Tracking reports for United States satellites are received quite regularly by AGIWARN through SPACEWARN channels from COSMOS, IONOSPHARE DARMSTADT, and NERA for tracking stations in their regions. In 1960, AGIWARN received 87 such messages concerning 18 US satellites. Tracking reports of USSR satellites were forwarded from AGIWARN to COSMOS. It is not known to what extent reports are forwarded through SPACEWARN channels from other SRWC's, although a number of stations apparently send data through the Darmstadt SRWC.

Message Code Words

The code words now in common use are the following:

SATOR:	Current (modified) orbital elements
SATOF:	Optical tracking observations
SATUG:	Optical tracking observations
COSMOS:	Optical tracking observations

The definitive description and key to SATOR are given in *IGY Satellite Report Series Number 7*, available from IGY World Data Center A, US National Academy of Sciences, 2101 Constitution Avenue, N.W., Washington 25, D. C. A version that appears in the "IGY Instruction Manual for World Days and Communications," *IGY Annals*, Vol. VII, Part I, Pergamon Press, 1959, is also usable, and contains descriptions and keys to the other codes as well.

Distribution of Messages

Each of the Satellite Regional Warning Centers is responsible for arranging to forward messages to interested national centers or individual laboratories within its region. Details of such arrangements vary widely, according to practical possibilities, and no attempt is made to arrange a uniform pattern. A complete census of the use of SPACEWARN channels within regions is not available at present, although it appears likely that more than 100 institutions and stations are served. Institutions desiring satellite prediction information should get in touch with the appropriate Satellite Regional Warning Center (above).

1961 COSPAR Modifications of SPACEWARN Plan

In accordance with recommendations adopted by COSPAR in April 1961 at its meeting in Florence, Italy, a number of improvements are being made in the SPACEWARN plan. Among them are the following: All messages are to be identified as SPACEWARN messages, and revised codes for the various types of SPACEWARN messages are to be issued by autumn of 1961. Abbreviated launching announcements and current orbital predictions in the SATOR code are being added to daily broadcasts of solar and geophysical data by the URSIgramme centers at Bagneux (Paris) and Kokubunji (Tokyo). COSPAR also suggested that similar broadcasts in other regions might help to improve the effectiveness of regional distribution of SPACEWARN data.

Each national member of COSPAR is to designate an individual to be the national contact for SPACEWARN to help identify the stations requiring SPACEWARN messages and to recommend changes or improvements necessary to assure effective communication in their areas.

Man's Role in Space

With the recent announcement by President Kennedy that manned landing on the Moon constituted a national objective of the space program during the present decade, public discussion has been concerned with the values of such an effort. For three years the Space Science Board of the National Academy of Sciences has been studying scientific aspects of space, including the role of man. On this topic the Board adopted a formal position at its February 10-11, 1961 meeting, which it submitted to the Government on March 31, 1961.

The Space Science Board has recommended that *scientific exploration of the Moon and planets should be clearly stated as the ultimate objective of the U. S. space program for the foreseeable future.* This objective should be promptly adopted as the official goal of the United States space program and clearly announced, discussed and supported. In addition, it should be stressed that the United States will continue to press toward a thorough scientific understanding of *space,* of solving problems of manned space exploration, and of development of applications of space science for man's welfare.

The Board concluded that it is not now possible to decide whether man will be able to accompany *early* expeditions to the Moon and planets: many intermediate problems remain to be solved. However, the Board strongly emphasized that planning for scientific exploration of the Moon and planets must at once be developed on the premise that man will be included. Failure to adopt and develop our national program upon this premise will inevitably prevent man's inclusion, and every effort should be made to establish the feasibility of manned space flight at the earliest opportunity.

From a scientific standpoint, there seems little room for dissent that man's participation in the exploration of the Moon and planets will be essential, if and when it becomes technologically feasible to include him. Man can contribute critical elements of scientific judgment and discrimination in conducting the scientific exploration of these bodies which can never be fully supplied by his instruments, however complex and sophisticated they may become. Thus, carefully planned and executed manned scientific expeditions will inevitably be the more fruitful. Moreover, the very technical problems of control at very great distances, involving substantial time delays in command signal reception, may make perfection of planetary experiments impossible without manned controls on the vehicles.

There is also another aspect of planning this country's program for scientific exploration of the Moon and planets which is not widely appreciated. In the Board's view, the scale of effort and the spacecraft size and complexity required for manned scientific exploration of these bodies is unlikely to be greatly different from that required to carry out the program by instruments alone. In broad terms, the primary scientific goals of this program are immense: a better understanding of the origins of the solar system and the universe, the investigation of the existence of life on other planets and, potentially, an understanding of the origin of life itself. In terms of conducting this program a great variety of very intricate instruments (including large amounts of auxiliary equipment, such as high-powered transmitters, long-lived power supplies, electronics for remote control of instruments and, at least, partial data processing) will be required. It seems obvious that the ultimate investigations will involve spacecraft whether manned or unmanned, ranging to the order of hundreds of tons so that the scale of the vehicle program in either case will differ little in its magnitude.

Important supporting considerations are essential to realization of these concepts:

(a) Development of new generations of space vehicles, uniquely designed for use in space research and not adaptations of military rockets, must proceed with sufficient priority to ensure that reliable vehicles of adequate thrust are available for lunar and planetary research. This program should also include development of nuclear stages as rapidly as possible.

(b) Broad programs designed to determine man's physiological and psychological ability to adapt to space flight must likewise be pushed as rapidly as possible. However, planning for "manned" scientific exploration of the Moon and the planets should be consummated only as fast as possible consistent with the development of all relevant information. The program should not be undertaken on a crash basis which fails to give reasonable attention to assurance of success or tries to by-pass the orderly study of all relevant problems.

(c) Consideration should be given soon to the training of scientific specialists for spacecraft flights so that they can conduct or accompany manned expeditions to the Moon and planets.

The Board strongly urges official adoption and public announcement of the foregoing policy and concepts by the U. S. Government. Furthermore, while the Board has here stressed the importance of this policy as a *scientific* goal, it is not unaware of the great importance of other factors associated with a United States man in space program. One of these factors is, of course, the sense of national leadership emergent from bold and imaginative U. S. space activity. Second, the members of the Board as individuals regard man's exploration of the Moon and planets as potentially the greatest inspirational venture of this century and one in which the entire world can share; inherent here are great and fundamental philosophical and spiritual values which find a response in man's questing spirit and his intellectual self-realization. Elaboration of these factors is not the purpose of this document. Nevertheless, the members of the Board fully recognize their parallel importance with the scientific goals and believe that they should not be neglected in seeking public appreciation and acceptance of the program.

The membership of the Space Science Board and its committees, which includes leading scientists in various fields from all parts of the country, includes:

The Board: L. V. Berkner (Chairman), Harrison S. Brown, Leo Goldberg, H. Keffer Hartline, Donald F. Hornig, William W. Kellogg, Christian J. Lambertsen, Joshua Lederberg, Colin S. Pittendrigh, Richard W. Porter, Bruno B. Rossi, Alan H. Shapley, John A. Simpson, Harold C. Urey, James A. Van Allen, O. G. Villard, Jr., Harry Wexler, George P. Woollard, Hugh Odishaw (Executive Director), and R. C. Peavy (Secretary).

Committee on the Chemistry of Space and Exploration of Moon and Planets: Harold C. Urey (Chairman), Harrison S. Brown (Vice Chairman), Harry H. Hess, A. R. Hibbs, Mark Inghram, Zdenek Kopal, Gordon J. F. MacDonald, Frank Press, William M. Sinton, G. de Vaucouleurs, Fred L. Whipple, G. A. Derbyshire (Secretary).

Committee on Optical and Radio Astronomy: Leo Goldberg (Chairman), Lawrence H. Aller, Horace W. Babcock, Gerald M. Clemence, A. D. Code, John W. Evans, Jr., John Findlay, Herbert Friedman, Roger Gallet, G. H. Herbig, Frederick T. Haddock, Jr., Walter Orr Roberts, Lyman Spitzer, Jr., Martin Schwarzschild, Edward R. Dyer (Secretary).

Committee on International Relations: Richard W. Porter (Chairman), Herbert Friedman, Leo Goldberg, Hugh Odishaw, Homer E. Newell, Jr., Howard P. Robertson, Alan H. Shapley, Harry Wexler, Joel Orlen (Secretary).

Committee on Space Projects: Bruno B. Rossi (Chairman), Thomas Gold, Salvador E. Luria, Philip Morrison, J. P. T. Pearman (Secretary).

Committee on The Atmospheres of the Earth and Planets: Alan H. Shapley (Chairman), Henry G. Booker, Joseph W. Chamberlain, Robert Jastrow, C. Gordon Little, Laurence A. Manning, Arthur H. Waynick, R. C. Peavey (Secretary).

Committee on Physics of Fields and Particles in Space: John A. Simpson (Chairman), James A. Van Allen (Vice Chairman), Joseph Chamberlain, William Kraushaar, Eugene N. Parker, E. H.

Vestine, John Winckler, J. P. T. Pearman (Secretary).

Committee on Meteorological Aspects of Satellites: Harry Wexler (Chairman), Charles C. Bates, George Benton, Sigmund Fritz, William W. Kellogg, Norman Phillips, Ernst Stuhlinger, Verner E. Suomi, William K. Widger, Jr., Edward R. Dyer (Secretary).

Committee on Geodesy: G. P. Woollard (Chairman), R. K. C. Johns, D. A. Lautman, William Markowitz, W. J. O'Sullivan, Donald A. Rice, Hellmut Schmid, Charles A. Whitten, Edward R. Dyer (Secretary).

Committee on Upper Atmosphere Rocket Research: W. W. Kellogg (Chairman), H. J. aufm Kampe, Warren W. Berning, W. W. Elam, Robert D. Fletcher, Herbert Friedman, Stanley M. Greenfield, John E. Masterson, Willis Webb, Harry Wexler, G. A. Derbyshire (Secretary).

Committee on Exobiology: Joshua Lederberg (Chairman), Paul Berg, Melvin Calvin, Richard Davies, Norman Horowitz, A. G. Marr, Daniel Mazia, Aaron Novick, Carl Sagan, C. B. van Niel, Harold Weaver, G. A. Derbyshire (Secretary).

Committee on Environmental Biology: Colin S. Pittendrigh (Chairman), Allan H. Brown, Theodore H. Bullock, G. A. Derbyshire (Secretary).

Committee on Man in Space: Christian J. Lambertsen (Chairman), Howard J. Curtis, James D. Hardy, H. Keffer Hartline, James Henry, Joshua Lederberg, Norton Nelson, Colin S. Pittendrigh, R. W. Porter, John W. Senders, G. A. Derbyshire (Secretary).

Bibliographic Notes

Anderson, V. H., A technique for photographing snow-pit stratigraphy. *Journal of Geophysical Research, 65*(3) 1080–82, March 1960.

Athay, R. G., Phenomena of the solar atmosphere. *Science, 132*(3429), 707–711, September 16, 1960.

Bandeen, W. R., Manger, W. P., Angular motion of the spin axis of the Tiros I meteorological satellite due to magnetic and gravitational torque. *Journal of Geophysical Research, 65*(9), 2992–95, September 1960 (*National Aeronautics and Space Administration Technical Note D-571,* 6 p., 1961).

Brenner, J. L., Latta, G. E., The theory of satellite orbits, based on a new co-ordinate system. *Proceedings of the Royal Society,* Series A, *258* (1295), 470–85, November 8, 1960.

Brockman, J. F., Solar disturbances and radio communication forecasts. *Sky and Telescope, 21*(6), 322–26, June 1961.

Chubb, T. A., Friedman, H., Kreplin, R. W., X-ray emission accompanying solar flares and nonflare sunspot maximum conditions. *Space Research,* H. K. Kallmann Bijl, ed., North-Holland Publishing Company, Amsterdam, and Interscience Publishers, Inc., New York, Part IV, 695–701, 1960.

Crary, A. P., Glaciological regime at Little America Station, Antarctica. *Journal of Geophysical Research, 66*(3), 871–78, March 1961.

Danielson, R. E., An attempt to detect energetic gamma radiation from the sun. *Journal of Geophysical Research, 65*(7), 2055–59, July 1960.

Dodson, H. W., Hedeman, E. R., Survey of the number of solar flares observed during the International Geophysical Year. *Journal of Geophysical Research, 65*(1), 123–131, January 1960..

Fan, C. Y., Simpson, J. A., Experiments on the eleven-year changes of cosmic-ray intensity using a space probe. *Physical Review Letters, 5*(6), 272–4, September 15, 1960.

Fan, C. Y., Meyer, P., Simpson, J. A., Preliminary results from the space probe Pioneer V. *Journal of Geophysical Research, 65*(6), 1862–3, June 1960.

Fan, C. Y., Meyer, P., Simpson, J. A., Rapid reduction of cosmic-radiation intensity measured in interplanetary space. *Physical Review Letters, 5*(6), 269–71, September 15, 1960.

Fritz, S., Wexler, H., Cloud pictures from satellite Tiros I. *Monthly Weather Review, 88*(3), 79–87, March 1960.

Giddings, J. C., LaChapelle, E., Diffusion theory applied to radiant energy distribution and albedo of snow. *Journal of Geophysical Research, 66*(1), 181–9, January 1961.

Hess, W. N., Canfield, E. H., Lingenfelter, R. E., Cosmic-ray neutron demography. *Journal of Geophysical Research, 66*(3), 665–77, March 1961.

Hubert, L. F., Fritz, S., Wexler, H., Pictures of the earth from high altitudes and their meteorological significance. *Space Research,* H. K. Kallmann Bijl, ed., North-Holland Publishing Company, Amsterdam, and Interscience Publishers, Inc., New York, Part I, 3–7, 1960.

Hubert, L. F., A subtropical convergence line of the South Pacific. *Journal of Geophysical Research, 66*(3), 797–812, March 1961.

Izsak, I. G., Orbit determination from simultaneous doppler-shift measurements. *Smithsonian Astrophysical Observatory Special Report No. 38,* 12 p., January 15, 1960.

Izsak, I. G., A theory of satellite motion about an oblate planet: I. A second-order solution of Vinti's dynamical problem. *Smithsonian Astrophysical Observatory Special Report No. 52,* 54 p., November 21, 1960.

Johnson, D. S., Image sensing as applied to meteorological satellites. *Journal of the Society of Motion Picture and Television Engineers, 69*(1), 14–18, January 1960.

Kasper, J. E., Geomagnetic effects on cosmic radiation for observation points above the earth.

Journal of Geophysical Research, 65(1), 39–53, January 1960.

Katz, A. H., Observation satellites: Problems and prospects (6-part article). *Astronautics, 5*(4), 26–29, 74–80, April 1960; *5*(6), 26–29, 52–54, June 1960; *5*(7), 28–29, 80–85, July 1960; *5*(8), 30–31, 59–60, August 1960; *5*(9), 32–33, 40–46, September 1960; *5*(10), 36–40, October 1960.

Licht, A. L., Properties of the solar wind during sunspot maximum. *Journal of Geophysical Research, 65*(5), 1397-1400, May 1960.

McDonald, F. B., Webber, W. R., The variation of the cosmic ray intensity during a solar cycle. *Space Research,* H. K. Kallmann Bijl, ed., North-Holland Publishing Company, Amsterdam, and Interscience Publishers, Inc., New York, Part V, 968–81, 1960.

Maxwell, A., Howard, W. E., III, Garmire, G., Some statistics of solar radio bursts at sunspot maximum. *Journal of Geophysical Research, 65*(11), 3581–88, November 1960.

Mesner, M. H., Steniszewski, J. R., Television cameras for space exploration. *Astronautics, 5*(5), 36–37, 126–130, May 1960.

Meyer, P., Cosmic radiation research in the United States. *Transactions, American Geophysical Union, 41*(2), 249–53, June 1960..

Meyer, P., The cosmic ray alpha-particle flux during sharp Forbush intensity decreases. *Journal of Geophysical Research, 65*(12), 3881–87, December 1960.

Meyer, P., Vogt, R., Electrons in the primary cosmic radiation. *Physical Review Letters, 6*(4), 193–96, February 15, 1961.

Myers, G. H., Thompson, T. H., Guidance of Tiros I. *ARS Journal, 31*(5), 636–40, May 1961.

Neiburger, M., Wexler, H., Weather satellites. *Scientific American, 205*(1), 80–94, July 1961.

Péwé, T. L., Glacial history of the McMurdo Sound Region, Antarctica. *Report of the International Geological Congress,* XXI Session Norden, 71–80, 1960.

Pomerantz, M. A., Agarwal, S. P., Potnis, V. R., Balloon flight investigations of primary cosmic rays during solar disturbances. *Journal of the Franklin Institute, 269*(3), 235–44, March 1960.

Reder, F. H., Winkler, M. R., World-wide clock synchronization. *IRE Transactions on Military Electronics, MIL-4*(2/3), 366–76, April-July 1960.

Seminar Proceedings: Tracking Programs and Orbit Determinations, February 23–26, 1960. *Astronautics Information,* Jet Propulsion Laboratory, 208 p., 1960.

Simpson, J. A., The acceleration and propagation of particles within the solar system. *Science in Space,* L. V. Berkner and H. Odishaw, eds., McGraw-Hill Book Company, Inc., Part 5, 239–59, 1961.

Simpson, J. A., Fan, C. Y., Meyer, P., Cosmic radiation intensity decreases observed at the earth and in the nearby planetary medium. *Physical Review Letters, 4,* 421, 1960.

Siry, J. W., Satellite and space probe orbit determinations—past, present and future. *Space Trajectories,* Academic Press, New York, 9–13, 1960.

Special Section on Tiros I. *Astronautics, 5*(6), June 1960.

Symposium on the July 1959 [Solar-Terrestrial] Events and Associated Phenomena, Helsinki, July 1960. *IUGG Monograph No. 7,* 157 p. November 1960.

Tamai, E., Heavy nuclei in the primary cosmic rays over Minnesota. *Physical Review, 117*(5), 1345–51, March 1, 1960.

Tepper, M., Tiros program results. *Astronautics, 6*(5), 28–29, 82–87, May 1961.

U. S. Meteorological Satellite cameras photograph cloud cover. *Science, 131*(3406), 1031–33, April 8, 1960.

Waddington, C. J., The relative abundances of the heavy nuclei in the primary cosmic radiation. *Philosophical Magazine, 5*(52), 311–23, April 1960.

Williams, W. E., Space telemetry systems. *Proceedings of the IRE, 48*(4), 685–90, April 1960.

Winckler, J. R., Primary cosmic rays. *In* Proceedings of Conference on Radiation Problems in Manned Space Flight, June 21, 1960, Washington D. C., G. J. Jacobs, ed., *NASA Technical Note D-588,* Appendix A, 72-99, December 1960.

Winckler, J. R., Balloon study of high-altitude radiations during the International Geophysical Year. *Journal of Geophysical Research, 65*(5), 1331–59, May 1960.

Woollard, G. P., Antarctic magnetic program. *Science in Antarctica, Part II,* National Academy of Sciences—National Research Council Publication 878, 95-97, 1961.

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